Health Consultation

Evaluation of Polychlorinated Biphenyls (PCBs) in Spokane River Fish

Spokane, Spokane County, Washington

March 27, 2001

Prepared by
The Washington State Department of Health
under a Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

Washington State Department of Health

Acknowledgements

The Washington State Department of Health would like to thank Lon Kissinger of the Washington State Department of Ecology for both his detailed review and research in support of this consultation. We are also grateful to Dr. William C. Griffith of the University of Washington, Department of Environmental Health for statistical analysis and guidance.

Foreword

The Washington State Department of Health (DOH) has prepared this health consultation in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the U.S. Department of Health and Human Services and is the principal federal public health agency responsible for health issues related to hazardous waste. This health consultation was prepared in accordance with methodologies and guidelines developed by ATSDR.

The purpose of this health consultation is to identify and prevent harmful human health effects resulting from exposure to hazardous substances in the environment. The health consultation allows DOH to respond quickly to a request from concerned residents for health information on hazardous substances. It provides advice on specific public health issues. DOH evaluates sampling data collected from a hazardous waste site, determines whether exposures have occurred or could occur, reports any potential harmful effects, and recommends actions to protect public health.

For additional information or questions regarding DOH, ATSDR or the contents of this health consultation, please call the Health Advisor who prepared this document:

Robert Duff
Toxicologist
Washington State Department of Health
Office of Environmental Health Assessments
P.O. Box 47846
Olympia, WA 98504-7846
Phone: 1-877-485-7316
Fax: (360) 236-3383
email: robert.duff@doh.wa.gov
office web page: http://www.doh.wa.gov/ehp/oehas/default.htm

Glossary

Agency for Toxic Substances and Disease Registry (ATSDR)	The principal federal public health agency involved with hazardous waste issues, responsible for preventing or reducing the harmful effects of exposure to hazardous substances on human health and quality of life. ATSDR is part of the U.S. Department of Health and Human Services.
Carcinogen	Any substance that can cause or contribute to the production of cancer.
Chronic	A long period of time. A chronic exposure is one that lasts for a year or longer.
Contaminant	Any chemical that exists in the environment or living organisms that is not normally found there.
Dose	A dose is the amount of a substance that gets into the body through ingestion, skin absorption or inhalation. It is calculated per kilogram of body weight per day.
Epidemiology	The study of the occurrence and causes of health effects in human populations. An epidemiological study often compares two groups of people who are alike except for one factor, such as exposure to a chemical or the presence of a health effect. The investigators try to determine if any factor (i.e., age, sex, occupation, economic status) is associated with the health effect.
Exposure	Contact with a chemical by swallowing, by breathing, or by direct contact (such as through the skin or eyes). Exposure may be short-term (acute) or long-term (chronic).
Hazardous substance	Any material that poses a threat to public health and/or the environment. Typical hazardous substances are materials that are toxic, corrosive, ignitable, explosive, or chemically reactive.
Indeterminate public health hazard	Sites for which no conclusions about public health hazard can be made because data are lacking.
Ingestion rate	The amount of an environmental medium that could be ingested typically on a daily basis. Units for IR are usually liter/day for water, and mg/day for soil.
Minimal Risk Level (MRL)	An amount of chemical that gets into the body (i.e. dose) below which health effects are not expected. MRLs are derived by ATSDR for acute, intermediate, and chronic duration exposures by the inhalation and oral routes. Chronic oral MRLs are similar to EPA's oral reference doses (RfDs).
Oral Reference Dose (RfD)	An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs are published by EPA and are given in milligrams of chemical per kilogram body weight per day (mg/kg-day).

Parts per billion (ppb)/Parts per million (ppm)	Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm. 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE.
Risk	The probability that something will cause injury, linked with the potential severity of that injury. Risk is usually indicated by how many extra cancers may appear in a group of people who are exposed to a particular substance at a given concentration, in a particular pathway, and for a specified period of time. For example, a 1%, or 1 in 100 risk indicates that for 100 people who may be exposed, 1 person may experience cancer as a result of the exposure.
Route of exposure	The way in which a person my contact a chemical substance that includes ingestion, skin contact and breathing.
U.S. Environmental Protection Agency (EPA)	Established in 1970 to bring together parts of various government agencies involved with the control of pollution.

Background and Statement of Issues

The Washington State Department of Health (DOH) was asked to review and evaluate health risks that may result from the exposure to polychlorinated biphenyls (PCBs) through consumption of Spokane River fish. The Spokane Regional Health District (SRHD) issued notices in 1994 and 1995 advising fishing enthusiasts that PCB concentrations in Spokane River fish were of concern. This consultation is in response to newly acquired data, which provides for a more comprehensive evaluation of potential risk due to the consumption of fish from the Spokane River. To conduct this evaluation, DOH worked jointly with the Washington State Department of Ecology (Ecology) and SRHD. DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substance and Disease Registry (ATSDR).

Polychlorinated Biphenyls (PCBs)

PCBs are a group of human-made chlorinated organic chemicals that were first introduced into commercial use in 1929 as insulating fluids for electric transformers and capacitors. Other applications were soon developed that included their use in hydraulic fluids, paint additives, plasticizers, adhesives, and fire retardants. Production of PCBs in the United States stopped in 1977 following concerns over toxicity and persistence in the environment.[1,2]

There are 209 structural variations of PCBs called congeners that vary by the number and location of chlorine atoms on the base structure. In the Untied States, PCBs were produced by the Monsanto Company and given the trade name, Aroclor. Aroclors are various mixtures of congeners defined by a four-digit number. The first two digits represent the number of carbon atoms (12) while the second two digits give the percent chlorine by weight for the congeners in that mixture.[a] In general, PCB persistence and toxicity increases with the degree of chlorination in the mixture.

Environmental Sampling

In 1990, Ecology sampled fish and sediment in the Spokane River Arm of Lake Roosevelt. Results showed that PCBs were above levels found in other rivers and lakes throughout the state. Further sampling of fish and sediment from the upper Spokane River in 1993, 1994 and 1996 also showed elevated levels of PCBs. The largest sources of PCBs are located between the Washington/Idaho state line and Upriver Dam (see Appendix A, Figure 1).[3,4,5] These findings prompted SRHD to issue statements of caution regarding the consumption of fish taken from the river.[6]

Many of the fish and sediment samples collected from the Spokane River were also found to contain elevated levels of lead. This finding recently prompted SRHD to issue a fish advisory for the upper Spokane River.[7] Mining operations in the Coeur d'Alene Basin are thought to be responsible for elevated levels of metals that have been found in Spokane River fish and sediment.[3]

Ecology and the United States Geological Survey (USGS) conducted more recent sampling and analysis for PCBs in Spokane River fish during July and October 1999.[8] Sampling sites ranged

[a] Aroclor-1016 does not follow this naming convention.

from just west of Washington/Idaho state line near river mile 96, down river to the Seven Mile Bridge area at river mile 63 (Figure 1). Table 1 below summarizes the results of this analysis. Total PCB concentrations represent the sum of Aroclors-1248, -1254 and -1260. Both fillet and whole fish samples were analyzed. Fillet samples represent individual fish while whole fish samples are composites of five individuals.

Aroclors are PCBs

Different methods are used to detect PCBs in fish. The results presented here, as total PCBs, are the sum of three different mixtures of PCBs called Aroclor-1248, -1254 and -1260, which are commonly found in fish. More specific analysis of individual congeners was also performed to provide a measure of dioxin toxic equivalents (TEQ) (see Appendix C).

Table 1. Total PCB concentrations in 1999 Spokane River fish samples (ppb, wet weight)

Location	Species	Tissue [a]	Samples	Result		
				Mean	95-UCL	Maximum
WA/ID state line (River mile 96)	Large scale suckers	Whole	1	-	-	120
		Fillet	5	101	230	342
	Rainbow trout	Whole	1	-	-	77
		Fillet	5	108	122	133
Plante Ferry Park (River mile 85)	Large scale suckers	Whole	1	-	-	283
		Fillet	5	148.0	182	215
	Rainbow trout	Whole	1	-	-	755
		Fillet	5	880	1312	1610
	Crayfish	Whole	1	-	-	*22.5*
Greene Street (River mile 77)	Large scale suckers	Whole	1	-	-	445
		Fillet	5	192	314	429
	Rainbow trout	Whole	1	-	-	362
		Fillet	5	226	314	398
	Mountain whitefish	Whole	1	-	-	397
		Fillet	5	339	402	478
	Crayfish [a]	Whole	1	-	-	20.6
Seven Mile Bridge (River mile 63)	Large scale suckers	Whole	1	-	-	680
		Fillet	5	146.9		
	Rainbow trout [b]	Whole	1	-	-	221
		Fillet	5	146	239	363
	Rainbow trout	Fillet	2	135		
	Mountain whitefish	Whole	1	-	-	930
		Fillet	5	642	1302	1880
	Crayfish	Whole	1	-	-	*22.5*

ppb = parts per billion. 95-UCL = 95 percent upper confidence limit on the mean.
a = Whole body samples are composites of 5 fish, fillets are individual fish. Results of whole body composites are given as maximums.
b = Crayfish sample taken near Trent Avenue Bridge.
c = Denotes hatchery raised rainbow trout. All other trout samples are from wild fish.
NOTE: Values in *italics* represent one-half the detection limit for samples in which no Aroclors were detected.

PCB Toxic Equivalents (PCB-TEQs)

Some PCB congeners have a structure and biological activity that is similar to dioxin. Toxic equivalency factors (TEFs) are used to account for the potential of these congeners to exert dioxin-like toxicity. TEFs are available for 12 dioxin-like PCB congeners.[9] Each congener is multiplied by its TEF to give the dioxin toxic equivalent value (TEQ). The TEQs for each congener are then summed to give the overall PCB-TEQ. TEFs for each congener are based on the toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin.

PCB-TEQ data for Spokane River fish was difficult to interpret quantitatively because of limited sample numbers and high detection limits. A qualitative analysis of the data and its limitations is given in Appendix C.

Historical Data

A comparison of four common locations that were sampled in 1993, 1994 and 1996 indicates a decline in the PCB levels of Spokane River fish. However, this trend was not consistent for each species of fish at every location and is not considered a strong trend when results of recent sampling are considered.[3,5] This trend is also suspect based on the significantly lower levels of PCB found in 1994 versus 1993 samples. PCB levels in fish are not expected to drop measurably in one year regardless of source remediation.[10] Comparison of historical data with 1999 samples is complicated by the different locations chosen for this most recent sampling.

The 1999 data was chosen as the best data set for quantitative assessment. The 1999 sampling was more comprehensive than past years in terms of total samples, sample type and number of locations.

Discussion

In order to relate our knowledge of PCB toxicity to exposure associated with eating Spokane River fish, we must first assess the nature and extent of that exposure. Several assumptions must be made in order to estimate the PCB dose associated with eating Spokane River fish. These assumptions are based on the characteristics of the exposed population. Exposure parameters and equations used to calculate health risks are provided in Appendix B. The potential for adverse health impacts is then evaluated using health benchmark values available for the assessment of non-cancer and cancer endpoints.

The following discussion provides the health risk evaluation for populations of concern who consume fish from the Spokane River. A discussion of fish eating characteristics for populations of concern is followed by non-cancer and cancer health evaluations. Health risks are stratified by species of fish, meal preparation (i.e., whole versus fillet) and by toxic endpoint (i.e., non-cancer versus cancer). Finally, a comparison is made between the risks associated with consuming PCBs in Spokane River fish versus those associated with background levels of PCBs in Washington State freshwater fish.

Populations of Concern

It is important to define the fish eating characteristics for populations of concern in order to make good assumptions regarding the amount and frequency of fish consumption (i.e., fish ingestion rate). Recreational anglers are the primary users of the Spokane River above the Long Lake Reservoir Dam. A significant Native American population that fishes the upper river has not been identified and no tribal lands border the river between Long Lake and the Idaho state line. SRHD identified populations that frequently fish this area in a recent survey.[11] Populations that eat fish from the Spokane River include sport fishermen as well as various ethnic groups that supplement meals with fish from the river. Table 2 below gives fish consumption characteristics for those populations examined in the SRHD survey. As shown, most of the fishing in the Spokane River occurs below Seven Mile Bridge and is, therefore, outside of the sampling area considered in this assessment.

Table 2. Characteristics of populations that eat fish from the Spokane River, Washington

Population	Fishing Locations	Types of Fish Consumed	Common Fish Preparation	Consumption Rates
Recreational (Fish License Holders)	downstream of Seven Mile Bridge	walleye, perch, trout	skinned fillets or gutted fish	1-20 fish per year
Recreational (Walleye Club Members)	downstream of Seven Mile Bridge	walleye, trout	fillets or gutted fish	NA
Russian Community	nearest to Greene Street & Plantes Ferry Park	trout, crayfish, suckers	cutlets, ground (after removal of head and spine), pickling, drying	2 meals per month
Laotian Community	downstream of Seven Mile Bridge	trout, perch, bass, walleye, crayfish	NA	2-3 meals per month

NA= data not available

The following health risk evaluation is based on exposure of *recreational consumers*. Although the local SRHD study was useful in identifying populations of concern, two studies of nearby Lake Roosevelt anglers were used as the basis for quantitative estimates of ingestion rates.[12,13] The average and high-end fish ingestion rates used for this consumer group are 42 and 90 grams/day (g/day), respectively. As noted above, recreational fishers are the main population of concern for consumption of fish from the Spokane River. The use of the Lake Roosevelt data is considered to be protective of both the general population and high-end recreational consumers. However, some consumer groups, such as Russians and subsistence Native American consumers, could eat more fish than is estimated in this evaluation. A more complete discussion of fish consumption patterns among various groups who fish the Spokane River is given in Appendix C.

Non-cancer Risk Evaluation

In order to evaluate the potential for *non-cancer* adverse health effects that might result from exposure to PCBs in Spokane River fish, average and high-end doses were estimated for a recreational consumer. These estimated doses were then compared to minimal risk level (MRL). MRLs are doses below which non-cancer adverse health effects are not expected to occur (so called “safe” doses).[2] They are derived from toxic effect levels obtained from human population and laboratory animal studies. This toxic effect level is

Minimal Risk Level (MRL)
Different methods are used to select the toxic effect levels from which MRLs are derived. The most common method is to use a lowest-observed adverse effect level (LOAEL) or a no-observed adverse effect level (NOAEL). The MRL for PCBs is derived from a LOAEL based on immune system effects seen in monkeys fed Aroclor-1254 in their diets.

divided by “safety factors” to give the lower, more protective MRL. A dose that exceeds the MRL indicates only the potential for adverse health effects. The magnitude of this potential can be inferred from the degree to which this value is exceeded by the exposure dose. If the estimated exposure dose is only slightly above the MRL, then that dose will fall well below the toxic effect level. The higher the estimated dose is above the MRL, the closer it will be to the toxic effect level.

Doses calculated for average and high-end recreational consumers of Spokane River fish exceed the MRL for each fish species. The MRL is based on a lowest-observed adverse effect level (LOAEL) of 0.005 mg/kg-day where immune system changes were seen in monkeys exposed to Aroclor-1254 in their diet. This LOAEL was divided by an uncertainty factor of 300 to give an MRL of 0.00002 mg/kg-day.[2,b] The amount by which the MRL is exceeded by the exposure dose ranged from 4 to 50. Therefore, the maximum exposure dose calculated is 5-fold below the LOAEL. *The fact that high-end exposures approach the LOAEL for immune system effects to within an order of magnitude indicates that a population at risk does exist for this health endpoint.* Table 3 below provides the dose/MRL ratio (also known as the *hazard quotient*) calculated for average and high-end consumers of fish fillets for different species. Further stratification of these ratios, by sample location and sample type (i.e., fillet versus whole), is provided in Appendix B, Table B3.

Table 3. Polychlorinated biphenyl (PCB) dose/MRL ratios for recreational consumers of Spokane River fish fillets caught between the Washington/Idaho state line and Seven Mile Bridge

Fish Species	Consumer Group			
	Average		High-end	
	Dose (mg/kg-day)	Dose/MRL [a]	Dose (mg/kg-day)	Dose/MRL
Rainbow trout	0.00019	10	0.00063	30
Large scale suckers	0.00009	4	0.00025	12
Mountain whitefish	0.00029	15	0.0012	61

a = This is the exposure dose divided by the MRL and is also known as the hazard quotient.
MRL = minimal risk level = 0.00002 mg/kg/day.

Liver toxicity has been demonstrated in animals given high doses of PCBs.[14] Liver toxicity and developmental effects are also well documented in residents of Taiwan and Japan exposed to relatively high levels of PCBs through ingestion of contaminated rice oil. However, the association of these effects with PCB exposure is complicated by concurrent exposure to chlorinated dibenzofurans.[2]

While the “rice oil” incidents in Taiwan and Japan provide good evidence of PCB toxicity in humans, recent studies demonstrate that developmental effects can occur at lower levels of PCB exposure. Deficits in neurobehavioral function in children exposed *in utero* represent the most

[b] EPA provides an oral reference dose (RfD) for PCBs that is equivalent to and based on the same study as the MRL. RfDs have essentially the same definition as MRLs but the two are not always equivalent.[13] ATSDR recently completed an update of the PCB MRL and did not change it.

compelling evidence that environmental exposure to PCBs have caused adverse health effects in humans. Studies of various human populations exposed to PCBs, primarily through the ingestion of fish, have demonstrated deficits in neurobehavioral function. Learning deficits were maintained in the children of one Lake Michigan fish-eating cohort through 11 years of age. Animal studies have also shown adverse effects on development following pre-natal exposure of the fetus. [2,15]

Thyroid dysfunction has also been associated with PCB exposure. Several *in vitro* and animal studies have shown a reduction in thyroid hormone (thyroxine) levels in response to PCB exposure.[16,17,18] A study in rats exposed *in utero* to PCBs found hearing deficits concurrent with decreasing thyroxine levels.[19] This finding suggests that interference with thyroxine levels could be a mechanism for the developmental effects associated with children exposed to PCBs prior to birth. The potential for PCBs to disrupt hormone function, including the endocrine system, has been suggested as a mechanism for the reproductive effects of PCBs seen in animals. Some human epidemiological studies provide support for the reproductive toxicity of PCBs including effects on menstrual cycles in women and male fertility. [2,14]

ATSDR has recently reviewed their MRL considering the more recent human developmental studies discussed above. This review concluded that immune system effects seen in monkeys still represent the most sensitive toxic endpoint of PCB exposure. Further, ATSDR concluded that the existing MRL based on this endpoint should not change and would be protective of the developmental effects found in the more recent human epidemiological studies discussed above.[2] DOH is currently evaluating the available literature to determine the most appropriate health comparison value for PCB exposure.

Cancer Risk Evaluation

PCBs are classified as a Group B2 probable human carcinogen by EPA based on sufficient evidence of cancer in animals and inadequate evidence in humans.[13] Cancer risk estimates assume long-term exposure (i.e., 30 years) averaged over a 70-year lifetime. This average daily dose is then multiplied by a measure of toxicity, the cancer potency factor (or slope factor) to produce an estimate of carcinogenic risk.

Some cancer potency factors are derived from human population data; others are derived from laboratory animal studies involving doses much higher than are encountered in the environment. Use of animal data require extrapolation of the cancer potency obtained from these high dose studies down to real-world exposures. This process involves much uncertainty. Current thinking suggests that there is no “safe dose” of a carcinogen and that a very small dose of a carcinogen will give a very small cancer risk. Cancer risk estimates are, therefore, not *yes/no* answers but measures of chance (probability). The validity of the “no safe dose” assumption for cancer-causing chemicals is not clear. Some evidence suggests that certain chemicals considered to be carcinogenic must exceed a threshold of tolerance before initiating cancer. Despite the associated uncertainty, cancer risk estimates are useful in determining the magnitude of a cancer threat.

Table 4 below provides cancer risk estimates for average and high-end consumers of Spokane River fish. Estimates ranged from 8 cancers per 100,000 persons exposed to 1 cancer per 1,000 persons exposed based on the potencies developed for Aroclors-1254 and 1260.[20] Further stratification of cancer risk by sample location and sample type (i.e., fillet versus whole) is provided in Appendix B, Tables B4.

Table 4. Polychlorinated biphenyl (PCB) cancer risks for recreational consumers of Spokane River fish fillets caught between the Washington/Idaho state line and Seven Mile Bridge

Fish Species	Consumer Group	
	Average	High-end
Rainbow trout	2E-04	5E-04
Large scale suckers	8E-05	2E-04
Mountain whitefish	3E-04	1E-03

While high dose animal studies demonstrate that PCBs can cause liver tumors in rats, *evidence that PCBs can cause cancer in humans is conflicting*. Some studies have linked human exposure to organochlorines with breast cancer while other studies have found no association.[21,22,23,24,25,26,27] Other studies suggest a link between PCB exposure in humans and non-Hodgkin's lymphoma (NHL) based on higher PCB blood serum levels in NHL patients versus controls.[28,29] One recent analysis of a large cohort of workers exposed while manufacturing PCB containing transformers showed no increase in mortality despite high PCB blood serum levels.[30] The previously mentioned rice oil-poisoning incident in Taiwan did not reveal elevations in cancer mortality.[31] However, an examination of residents similarly exposed in Japan did show an increase in mortality from liver cancer.[32]

Health Risk Comparison with Background

The widespread presence of PCBs in fish throughout the United States and the world suggests that health risks associated with consumption of Spokane River fish be compared with an estimate of background risk.[2] The degree by which PCB concentrations in Spokane River fish exceed background is a useful consideration in determining public health actions.

Studies are available with which to estimate background PCB (Aroclor) levels in Washington State for comparison to Spokane River fish. However, developing precise estimates is complicated by differences in these studies that make comparisons difficult. In addition, the suitability of some data for human health risk assessment is compromised in that many of the analyses used whole body rather than fillet sample preparations.

A background range of 13 - 83 parts per billion (ppb) Aroclor (or total PCBs) in Washington State fish can be extracted from this data. Table 4 below summarizes data considered in estimating background levels of Aroclors in Washington State freshwater fish. Each of the potential sources of background data given in Table 5 below is discussed in Appendix E.

Table 5. Background concentrations of PCBs in fish tissue (ppb wet weight)

Source	Sample Type	Concentration Range
Analytical Limits	-	6-50
Washington State Department of Ecology	Fillet (rainbow trout)	13.3 (mean)
EPA Chemical Residues in Fish Tissue	NA	46.5 (mean)
Northern Rockies Intermontaine Basin (NRIB)	Whole body	50-83

NA = Not available

The Ecology mean PCB level of 13.3 ppb in rainbow trout fillets was determined to be the best background value for comparison purposes. Rainbow trout fillets represent a popular target of anglers and comprise a subset of the Spokane River fish data. Table 6 below compares PCB background levels and risks with those associated with eating Spokane River fish. Exposure assumptions used for this comparison were for the average fish consumer.

Table 6. Health risk comparison for PCBs in
Spokane River rainbow trout fillets versus background

Rainbow Trout Fillets	Concentration (ppb)	Dose/MRL	Cancer Risk
Spokane River	321.3	10	2E-4
Background	13.3	0.4	7E-6
Ratio: Spokane River/Background [a]	25		

ppb = parts per billion or ug/kg (micrograms PCB per kilogram fish), wet weight
a = Rounding will vary ratio. Mean concentrations and average ingestion rates were used for this comparison. See Table B1 for complete list of exposure assumptions.

The background comparison given above in Table 6 shows that rainbow trout from the Spokane River have 25-fold higher levels of PCBs than the trout from more pristine fresh water bodies in Washington State (i.e., low end of background).

This background comparison also illustrates that Spokane River fish have been impacted by a source of PCBs that is not universally affecting freshwater bodies throughout the state. It is clear, however, that other freshwater bodies in the region, with no known source, have higher levels of PCBs in fish. This fact is demonstrated by the relatively high PCB levels measured in fish taken from the Flathead River and Flathead Lake, Montana (see Appendix E).

Allowable Fish Consumption Rates

The local fish consumption survey discussed above identified several consumer groups that use the Spokane River for recreational fishing.[11] The risk evaluation based on exposure of these groups to PCBs in Spokane River fish indicates that recreational fishers are at risk for both non-cancer and cancer toxicity endpoints depending upon their consumption rate. *Because a population at risk exists, limits on fish consumption must be considered in order to protect the health of Spokane River fish consumers.*

Consumption rates were calculated for both average and high-end estimates of concentration for each species using Equation 1 in conjunction with the MRL as the target risk value and the exposure parameters provided in Appendix B, Table B1. Table 7 below provides fish consumption rates that would be protective of people who eat fish from the Spokane River. The concentration term was generated using two subsets of the data split at Upriver Dam. For comparison, limits are also shown using Plante Ferry data alone.

$$\text{Allowable Consumption Limit (g/day)} = \frac{BW \times AT_{non\text{-}cancer} \times MRL}{C \times CF_1 \times CF_2 \times EF \times ED} \qquad \textit{Equation 1}$$

Table 7. Allowable fillet consumption limits for consumers of various fish species caught from the Spokane River between WA/ID state line and Seven Mile Bridge

Fish Species	**PCB Concentration** (ppb)		**Allowable Ingestion Rate** (grams/day)		**Allowable 8 ounce meals per year**	
	Average	High-end [a]	Average	High-end	Average	High-end
Plante Ferry Park						
Rainbow trout	880	1312	1.6	1.1	2.6	1.7
Large scale suckers	148	182	9.5	7.7	15.2	12.4
Mountain whitefish	NA	NA	NA	NA	NA	NA
Above Upriver Dam to the WA/ID State Line [b]						
Rainbow trout	494	887	2.8	1.6	4.6	2.5
Large scale suckers	125	189	11.2	7.4	18.1	11.9
Mountain whitefish	NA	NA	NA	NA	NA	NA
Below Upriver Dam to the Seven Mile Bridge [c]						
Rainbow trout	177	242	7.9	5.8	12.7	9.3
Large scale suckers	170	244	8.3	5.7	13.3	9.2
Mountain whitefish	491	943	2.9	1.5	4.6	2.4

a = 95 percent upper confidence limit on the mean.
b = Includes Plante Ferry and the state line sampling locations.
c = Includes Greene Street and Seven Mile Bridge sampling locations.

The fillet meal limits proposed in Table 7 are considered to be protective of all fish consumers. A recent review by ATSDR indicates that the MRL is protective of both the immune system and the developing fetus.[2] However, the strength of the epidemiological evidence associating developmental effects with *in utero* exposure indicates that meal limits should be *emphasized for pregnant women and women considering pregnancy*.

It should be noted that these limits are based on fillet consumption. Higher levels of lead in whole fish samples across the three species as well as higher PCB levels in whole large scale sucker samples indicate that fillet preparation of meals can reduce exposure. *Children, age six years or younger, have been previously advised not to consume meals made from whole Spokane River fish due to elevated lead levels*.[7] Considering this data and that most consumers of Spokane River fish prepare their meals as fillets, meal limits were calculated assuming preparation as fillets.

Examination of the data by location revealed significant levels of PCBs in rainbow trout taken at Plante Ferry Park that were higher than PCB levels found in trout at other sampling locations. The relatively high PCB levels in trout taken from Plante Ferry translates into a limit of two or three meals per year. Combining Plante Ferry with the state line data gives a slightly higher trout consumption limit at three to five meals per year. The lack of a sampling point between Plante Ferry Park and the state line presents some difficulty in determining the levels of PCBs in fish caught upstream of Plante Ferry. The migration patterns of fish from Plante Ferry are not known but could extend several miles upstream. In addition, rainbow trout caught above Upriver Dam are likely to be larger, wild fish since no stocking occurs above this dam.[33, c] PCB levels generally increase with the size of the fish.[34] Because of potential migration of trout from Plante Ferry, a health protective decision was made to use the higher Plante Ferry data with which to calculate a fish consumption limit covering the area of the river from Plante Ferry to the state line.

It is clear that consumption of rainbow trout above Upriver Dam will result in a higher dose of PCBs than from trout below the dam. The dam likely serves as a barrier for downstream fish migration and is a known area of PCB sediment contamination. No mountain whitefish were caught for analysis above Upriver Dam. The relatively high levels of PCBs in mountain whitefish below Upriver Dam give cause for concern about the levels that might be found above the dam where discharge of PCBs and sediment contamination has been identified. Exposure to PCBs in fish could be significantly reduced if Plante Ferry Park is avoided as a fishing location. However, more data are needed to determine PCB levels in fish between Plante Ferry and the state line.

Other issues related to the Spokane River

The local fish consumption survey conducted by the SRHD indicates that the most common fishing locations on the Spokane River are between the Monroe Street Bridge and Spokane Arm of Lake Roosevelt. PCB levels in fish sampled in 1993 and 1994 from Long Lake appear to be lower than the levels found in fish above Nine Mile Dam (see Figure 1). Long Lake was not, however, sampled in 1996 or1999 and direct comparisons are difficult because of species differences.

Limited sampling in 1994 indicate that methyl mercury (MeHg) levels are elevated in walleye taken from the Spokane Arm of Lake Roosevelt Lake while other species do not appear to be accumulating MeHg to any significant extent.[35] These data are not evaluated in this report. It is important to note that DOH has an existing advisory for Lake Roosevelt limiting fish consumption to 20 meals per month based on dioxin and furan contamination.[36] In addition, DOH has a consumption advisory based on MeHg in walleye that recommends limiting consumption to: 8 meals per month for adults, 4 meals per month for pregnant women and women in childbearing years and 1/3 pound per month for children under 6 years of age.[37]

Crayfish from the Spokane River are consumed according to the local survey mentioned previously and discussed in Appendix D. Although sample data and consumption pattern information for crayfish are limited, PCB levels have consistently been below detection suggesting that crayfish consumption is not of health concern.

Chemical Exposure and Children

---

[c] Idaho does stock cutthroat and brown trout near the Post Falls area.

Children can be uniquely vulnerable to the hazardous effects of many environmental toxicants. Children six years of age and under are of primary concern when evaluating exposure to lead. The previous advisory issued for Spokane River fish recommended that children in this age group not consume whole fish meals because of the elevated levels of lead found in whole fish samples versus fillets. While the meal limits calculated in Table 7 are more restrictive than those calculated for the lead advisory, it is important for children age six and under to avoid whole fish meals. In order to encompass the protective approach taken in the previous advisory, young children should eat only *fillets* of Spokane River fish.

The developing fetus is clearly sensitive to PCB exposure. Evidence also exists to indicate that lead can exert development effects that are consistent with those associated PCBs. The developing fetus must, therefore, be considered when addressing health hazards posed by exposure to lead and PCBs. Although the MRL is based on immune system effects, it represents the most sensitive endpoint of PCB toxicity. Therefore, use of the PCB MRL to calculate meal limits is considered protective of both the developing fetus and the general population.

Benefits of Fish Consumption

It is important to consider the very real benefits of eating fish. Fish is an excellent source of protein and has been associated with reduced risk of coronary heart disease. The health benefits of eating fish have been associated with low levels of saturated versus unsaturated fats. Saturated fats are linked with increased cholesterol levels and risk of heart disease while unsaturated fats (e.g., omega-3 polyunsaturated fatty acid) are an essential nutrient. Fish also provide a good source of some vitamins and minerals.[38,39] The American Heart Association recommends two servings of fish per week as part of a healthy diet.[40]

The health benefits of eating fish deserve particular consideration when dealing with subsistence consuming populations. Removal of fish from the diet of subsistence consumers can have serious health, social and economic consequences that must be considered when issuing fish advisories.[36] No subsistence consuming populations that fish the Spokane River from the state line to Seven Mile Bridge were identified in this assessment.

The limits recommended in Table 7 for this part of the Spokane River are not expected to significantly impact fish consumption for sport fishers living in the Spokane area. As noted above, the most popular sport fishing locations are Long Lake and the Spokane River arm of Lake Roosevelt. Limited information from the SRHD survey indicate that the Russian community living in the Spokane area does fish the area of the river that is of concern. The recommended consumption limits could impact the amount of fish consumed by this group. Quantitative methods are available for assessing the overall health impact of fish consumption that offset risks and benefits to give an index of the net health impact.[35,41] These methods are beyond the scope of this assessment but should be considered in future evaluations.

Uncertainties associated with meal limits

It is important to note that the limits in Table 7 are based on an average adult weighing 70 kilograms who consumes eight ounces of fish per meal. Lake Roosevelt anglers reported eating about 11.3 ounces per meal while EPA estimates a mean intake for the general population of 129 grams per meal or 4.6 ounces.[11,42] An eight-ounce meal size was chosen as an easily identifiable size (i.e., one-half pound) that is within this range.

Applying the Table 7 meal limits across the general population assumes that meal size will decrease proportionately with body weight. Such an assumption could result in an underestimate of exposure for consumers who eat proportionately more fish per unit of body weight. Table 8 demonstrates how an eight-ounce meal for a 70-kilogram adult would change to remain proportional with body weight.

Table 8. Fish meal size adjusted for body weight [a]

Body Weight (lbs)	Body Weight (kg)	Body Weight Per 70 kg	Adjusted Meal Size (oz)
200	90.7	1.30	10.4
150	68.0	0.97	7.8
100	45.4	0.65	5.2
50	22.7	0.32	2.6
25	11.3	0.16	1.3
20	9.1	0.13	1.0

a = Based on an 8-ounce meal for a 70 kg adult.
lbs = ponds kg = kilograms

Cancer was not chosen as the endpoint with which to calculate meal limits. The data supporting the potential for PCBs to cause cancer in humans at the levels associated with environmental exposure is not clear while the non-cancer endpoints are well documented, particularly with respect to developmental effects in humans. Depending upon the target cancer risk chosen, the meal limits would be either more or less stringent if cancer was chosen as the endpoint of concern. The cancer risk associated with the allowable limits given in Table 7 can be estimated at 2 cancers per 100,000 persons exposed over a lifetime.[d] Cancer risk estimates using the PCB-TEQ approach could yield higher risks. EPA's guidance on fish advisories suggests the use of a target cancer risk of 1 cancer per 100,000 persons exposed.[43]

PCB exposure from fish consumption can be significantly reduced through preparation and cooking. Reduction of PCBs in the fish meal varies considerably by species and type of preparation. An average reduction of 30 percent was estimated for fat-trimmed, fillet meals of Great Lakes fish.[42] The Great Lakes Advisory Task Force previously used 50% reduction factor when calculating meal limits.[44] In considering the uncertainty discussed above, no reduction factor was employed in calculating the meal limits in Table 7. This fact could add up to a 2-fold margin of safety with respect to PCB exposure from Spokane River fish meals.

[d] This cancer risk was calculated by assuming a daily dose at the MRL of 0.00002 mg/kg-day for a duration of 30 years averaged over a 70 year lifetime. This gives a lifetime-average daily dose of 8.6E-6 mg/kg-day that can be multiplied by the Aroclor cancer potency factor of 2.0 per mg/kg-day to give a risk of 1.7E-05.

Conclusions

Exposure to polychlorinated biphenyls (PCBs) through ingestion of Spokane River fish caught between the Washington/Idaho border and Nine Mile Dam represents a public health hazard for persons who eat fish beyond the limits provided below (see Recommendations/Public Health Action Plan).[e]

- ♦ The potential for adverse health effects to result from eating Spokane River fish depends on several factors such as amount of fish consumed and fishing location.

The developing fetus is particularly susceptible to PCB toxicity. Both animal and human studies have demonstrated that children exposed in the womb to PCBs have learning problems during childhood years. Animal studies show that the immune system is another sensitive toxic endpoint of PCB exposure. Although high doses of PCBs can cause liver cancer in animals, PCB exposure has not been clearly linked to cancer in humans. Some evidence indicates a potential link between PCB exposure and non-Hodgkin's lymphoma and breast cancer.

Fish is a nutritious food and an excellent source of low-fat protein. Regular consumption of fish has been associated with a reduced risk of heart disease. The American Heart Association recommends two servings of fish per week as part of a healthy diet.

Levels of PCBs in fish found in the Spokane River from the Idaho State border to Seven Mile Bridge are higher then state averages. More sampling data from the Spokane River and other freshwater bodies throughout the state would be useful to better estimate background concentrations.

A recent local fish consumption survey indicates that most of the fishing in the Spokane River occurs between the Monroe Street Bridge and the Spokane Arm of Lake Roosevelt. Existing data indicate that PCB levels in fish from Long Lake are lower than those found in the upper portion of the Spokane River from Seven Mile Bridge to the state line. Insufficient data exists with which to characterize the health risks associated with consumption of PCBs in fish caught below Nine Mile Dam. Sport fishers should follow existing advisories for fish consumed from these lakes until further notice.

Future sampling of the Spokane River from Upriver Dam to the Washington/Idaho border needs to include more samples per location in order to better delineate areas of concern within this section of the river. In addition, areas of the river below Seven Mile Bridge (e.g., Long Lake) should be considered for sampling.

---

[e] The draft version of this document prompted a fish consumption advisory for the Spokane River that is available at http://www.doh.wa.gov/ehp/oehas/EHA_fish_adv.htm.

Recommendations/Public Health Action Plan

1. No one should eat rainbow trout or mountain whitefish caught between the Upriver Dam and the Idaho/Washington border.

    - Levels of PCBs found in rainbow trout at Plante Ferry Park were high compared to other locations sampled. Although no mountain whitefish samples were collected at Plante Ferry Park, the relatively high PCB levels found in whitefish below Upriver Dam indicate that this species does bioaccumulate PCBs to a significant extent. Historical sources of PCB discharge to the river and elevated levels of PCBs in sediment are known to exist above Upriver Dam.

    - PCB levels in rainbow trout caught at the state line are considerably lower than those near Plante Ferry Park. However, sampling is limited and the potential for migration of fish upstream from Plante Ferry suggests caution. Further sampling between Plante Ferry and the state line is needed to better estimate PCB levels in fish from this stretch of the river.

2. Consumption of rainbow trout and mountain whitefish caught between Upriver Dam and Nine Mile Dam should be limited to one meal per month and one meal every other month, respectively.

3. Consumption of large scale suckers caught between the Idaho/Washington border and Nine Mile Dam should be limited to one meal per month.

4. Existing advisories for this stretch of the Spokane River should be updated to reflect these new recommendations.

    - The new advisory should be posted at popular fishing spots along the Spokane River from the Idaho border to Nine Mile Dam.

5. The implementation of a systematic monitoring program is advised. Future sampling should include the same locations used in 1999 in order to determine whether existing consumption advisories need to be updated. An additional sampling location should be added between Plante Ferry Park and the Idaho border in order to better define PCB levels in fish above Upriver Dam.

    - Sampling plans should be reviewed by DOH to ensure their adequacy for health assessment purposes.
    - Congener specific analysis is recommended for at least one more sampling round. This analysis should include all 12 dioxin-like PCB congeners for which TEF values are currently available. Improved detection limits are required to provide adequate PCB-TEQ data for health assessment purposes.

6. Fish species commonly caught and eaten from Long Lake should be sampled and analyzed for PCBs.

- Local anglers indicate that areas below Seven Mile Bridge are the most popular fishing locations on the river. Although initial sampling indicates that PCB levels are lower in Long Lake fish, more sampling is necessary to adequately characterize exposure.
- Sampling plans should be reviewed by DOH to ensure their adequacy for health assessment purposes.

7. This consumption limits derived in this consultation should be re-examined pending new sampling and/or toxicological data.

Preparer of Report

Robert Duff
Office of Environmental Health Assessments
Washington State Department of Health

Appendix A: Figures

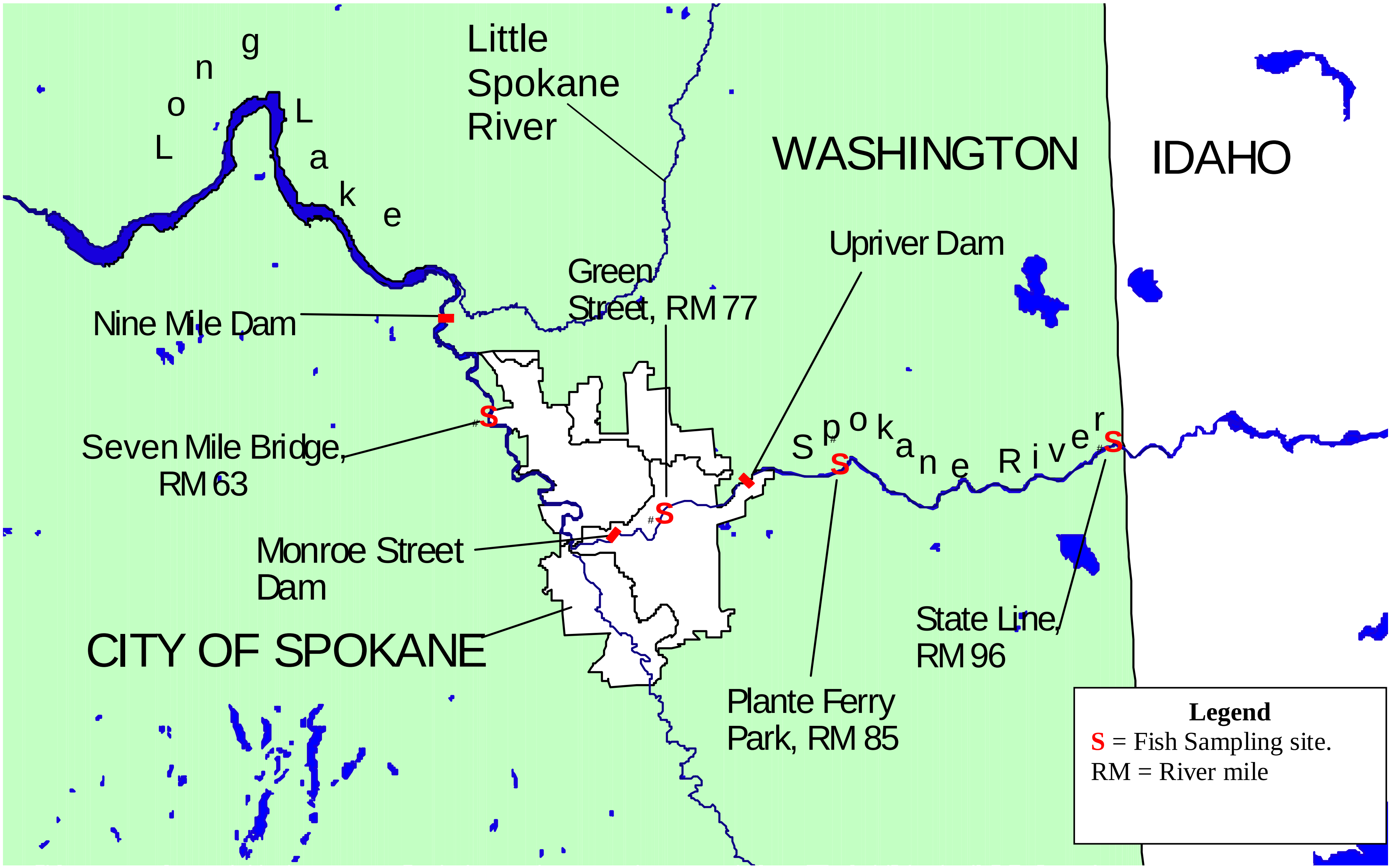

Figure 1. Sampling sites and areas of concern in the Spokane River based on polychlorinated biphenyl (PCB) contamination of fish.

Appendix B: Calculation of Health Risk Estimates

The human health risks associated with exposure to PCBs in Spokane River fish were evaluated for both cancer and non-cancer endpoints using the equations below and the exposure parameters provided in Table B1.

$$\text{Dose}_{\text{non-cancer (mg/kg-day)}} = \frac{C \times CF_1 \times IR \times CF_2 \times EF \times ED}{BW \times AT_{\text{non-cancer}}} \qquad \textit{Equation B1}$$

$$\text{Dose}_{\text{cancer (mg/kg-day)}} = \frac{C \times CF_1 \times IR \times CF_2 \times EF \times ED}{BW \times AT_{\text{cancer}}} \qquad \textit{Equation B2}$$

$$\text{Hazard Quotient} = \frac{\text{Dose}_{\text{non-cancer}}}{\text{MRL}} \qquad \textit{Equation B3}$$

$$\text{Cancer Risk} = \text{Dose}_{\text{cancer}} \times \text{Cancer Potency Factor} \qquad \textit{Equation B4}$$

Table B1. Exposure Assumptions

Parameter	Value	Unit	Comments
Concentration (C) - Average Concentration (C) - High-end	See Table B2	ppb (ug/kg)	Mean 95 UCL (fillet), maximum (whole fish)
Conversion Factor$_1$ (CF_1)	0.001	mg/ug	Converts PCB concentration from micrograms (ug) to milligrams (mg)
Ingestion Rate (IR) - Average	42	g/day	DOH Lake Roosevelt (Reference 11) and Spokane Tribe Creel Studies (Reference 12).
Ingestion Rate (IR) - High-end	90		
Conversion Factor$_2$ (CF_2)	0.001	kg/g	Converts mass of fish from grams (g) to kilograms (kg)
Exposure Frequency (EF)	365	days/year	Assumes daily exposure consistent with units of ingestion rate given in g/day.
Exposure Duration (ED)	30	years	High-end estimate of residence time.
Body Weight (BW)	70	kg	Adult mean body weight
Averaging Time$_{\text{non-cancer}}$ (AT)	10950	days	30 years
Averaging Time$_{\text{cancer}}$ (AT)	25550	days	70 years
Minimal Risk Level (MRL)	0.00002	mg/kg/day	Based on Aroclor-1254 from Reference 2.
Cancer Potency Factor	2	mg/kg-day^{-1}	Based on Aroclor-1254 and 1260 as described in Reference 19.

Table B2 below gives summary statistics for PCB levels in Spokane River fish. Mean concentrations shown for each sample subset were used with the average fish ingestion rate to generate risk estimates for the average consumer. High-end risk estimates for fillets were calculated using 95 percent upper-confidence limits on the mean. However, the small sample sizes for whole fish precluded calculating upper-confidence limits on the mean. High-end risk for whole fish was, therefore, estimated using either the 95th percentile or the maximum value detected. Table B3 and B4 provide the PCB cancer and non-cancer risk estimates.

The statistical method used to calculate the 95% upper confidence levels of the mean is referred to as the bootstrap. This is a nonparametric method that can be calculated for observations from any statistical distribution. It does not require you to have any prior knowledge about the type or shape of the distribution. The bootstrap, because it does not require any knowledge about the distribution, is a very versatile method. The statistical concepts it relies upon are that the distribution of the data are an estimate of the underlying distribution from which the observations are a random sample; and, if we draw samples from this approximate distribution and compute a statistic then by the central limit theorem the distribution of these statistics will be approximately normal. In our case the statistic we are computing from the data is the sample mean and we have drawn samples from the approximate distribution so that we could calculate 3,000 estimates of the mean. From these 3,000 estimates, we estimated the 95th percentile of the distribution, thus finding the 95% upper confidence limit of the mean. The particular software package used for this computation was S-Plus 2000. The bootstrap computation in this package also performs a correction for any bias in the statistic to improve the estimate of the upper confidence limit.[f]

Table B2. Summary statistics for PCBs detected in Spokane River fish caught at all locations between the Washington/Idaho state line and Seven Mile Bridge (ppb, wet weight)

Sample	Number of Samples	Mean	Standard Deviation	95th UCL	Maximum
Fillets					
Rainbow trout	22	321	456	545	1610
Large scale suckers	20	147	106	193	429
Mountain whitefish	10	491	500	943	1880
All	52	287	387	396	1880
Whole Fish					
Rainbow trout	4	354	292	696 [a]	755
Large scale suckers	4	382	239	645 [a]	680
Mountain whitefish	2	664	377	NA	930
All	10	427	281	581	930

a = Represents the 95th percentile. NA = Not applicable.

Table B3. PCB dose/MRL ratios for recreational consumers of Spokane River fish fillets caught between the Washington/Idaho state line and Seven Mile Bridge [a]

Sample	Stateline		Plante Ferry		Greene Street		Seven Mile bridge		All Locations	
	Average	High-end	Average	High-end	Average	High-end	Average	High-end	Average	High-end
Fillets										
Rainbow trout	3	8	26	84	7	20	4	15	10	35
Large scale suckers	3	15	4	12	6	20	4	13	4	12
Mountain whitefish	NA	NA	NA	NA	10	26	19	84	15	61
Whole Fish										
Rainbow trout	2	5	23	49	11	23	7	14	11	45
Large scale suckers	4	8	9	18	13	29	20	44	11	41
Mountain whitefish	NA	NA	NA	NA	12	26	28	60	20	60

a = The exposure dose divided by the MRL is also known as the hazard quotient. Any result above one indicates that the MRL is exceeded. MRL = minimal risk level = 0.00002 mg/kg/day.

[f] Further description of these methods can be found in B. Efron and R.J. Tibshirani, An Introduction to the Bootstrap, Chapman and Hall, New York, 1993 and S.R. Millard and N.K. Neerchal Environmental Statistics with S-Plus, CRC Press, New York, 2001.

Table B4. PCB cancer risks for recreational consumers of Spokane River fish fillets caught between the Washington/Idaho state line and Seven Mile Bridge

Species/ Sample Type	Stateline		Plante Ferry		Greene Street		Seven Mile bridge		All Locations	
	Average	High-end	Average	High-end	Average	High-end	Average	High-end	Average	High-end
Fillets										
Rainbow trout	6E-5	1E-4	5E-4	1E-3	1E-4	4E-4	7E-5	3E-4	2E-4	5E-4
Large scale suckers	5E-5	3E-4	8E-5	2E-4	1E-4	4E-4	8E-5	2E-4	8E-5	2E-4
Mountain whitefish	NA	NA	NA	NA	2E-4	4E-4	3E-4	1E-3	3E-4	1E-3
Whole Fish										
Rainbow trout	4E-5	9E-5	4E-4	8E-4	2E-4	4E-4	1E-4	2E-4	2E-4	8E-4
Large scale suckers	6E-5	1E-4	2E-4	3E-4	2E-4	5E-4	4E-4	8E-4	2E-4	7E-4
Mountain whitefish	NA	NA	NA	NA	2E-4	4E-4	5E-4	1E-3	3E-4	1E-3

Concentration Benchmarks

Table B5 provides PCB concentrations in fish that correspond to one allowable meal per week and one allowable meal per year. These concentrations were calculated using *Equation B5* in conjunction with the exposure assumptions given in Table B2 and ATSDR's MRL as the target dose.. .

$$\text{Concentration Benchmark (ppb)} = \frac{BW \times AT_{non\text{-}cancer} \times MRL}{IR \times CF_1 \times CF_2 \times ED \times EF} \qquad \textit{Equation B5}$$

Table B5. PCB concentrations in fish that correspond to the allowable intakes (ppb).

Allowable 8oz. Fish Meals per Year	PCB Level (ppb)
52	43
12	184

Appendix C: PCB-TEQ Analysis

The values given in Table C1 below represent the sum of individual TEQs calculated for 8 dioxin-like congeners. Four congeners for which TEF values exist were not included in the analyses. Although this omission could lead to an underestimation of the overall PCB-TEQ, the analysis did include the most toxic of the dioxin-like congeners, PCB-126. In other analyses, PCB-126, where present, accounted for over 95% of the total congener risk.[45] It is, therefore, unlikely that PCB-TEQ values are greatly underestimated by not having analyzed for all of the dioxin-like congeners. In addition, the analytical methods used for the congener specific analyses gave high detection limits compared with other methods. Since non-detects were included in the calculation of PCB-TEQs using one-half the detection limit, PCB-TEQ values may actually be overestimated.

Table C1. PCB-TEQ results for 1999 Spokane River fish samples (ppb, wet weight)

Location	Species	Tissue	PCB-TEQs Samples	PCB-TEQs Mean
Plante Ferry Park (River mile 85)	Large scale Sucker	Whole	1	0.092
		Fillet	3	0.065
	Rainbow Trout [a]	Whole	1	0.06
		Fillet	3	0.19
Greene Street (River mile 77)	Mountain Whitefish	Fillet	3	0.10

a = Wild rainbow trout

The PCB-TEQ values given in Table C1 were based on analyses with high detection limits and low percent detections for some congeners. The most common procedure when dealing with such data is to assign the non-detect samples a concentration of one-half the detection limit. The handling of detection limits can have significant effect on the final calculation of the PCB-TEQ concentration term. This fact is illustrated below in Table C2 that shows up to a 20-fold difference between PCB-TEQ values using the full detection limit value versus setting non-detects at zero. These differences are due in large part to the low detection frequencies and high TEF values associated with congeners PCB-126 (23%, TEF = 0.1) and PCB-169 (18%, TEF = 0.01).

Table C2. Impact of detection limits on PCB-TEQ values (ppb, wt weight)

Species (fillets)	Detection Limit x 1	Detection Limit x 0.5	Detection Limit x 0
Rainbow trout	0.32	0.19	0.06
Large scale suckers	0.12	0.065	0.006
Mountain whitefish	0.17	0.1	0.031

NOTE: No significant impact of detection limit treatment for Aroclor values is expected as very few non-detect results were reported.

It is also useful to note that the three samples in which PCB-126 was detected, all were qualified as estimates since the results were below the practical quantitation limit of the analytical method.

Since PCB-126 has the highest TEF value, inaccuracies in quantifying this congener will have a significant impact on the overall PCB-TEQ estimate. Table C3 below indicates that congener PCB-126 accounts for 69 to 85 percent of the overall PCB-TEQ value depending upon the fish species.

Table C3. PCB-TEQ values with and without congener PCB-126 (ppb, wt weight) [a]

Species (fillets)	Including PCB-126	Excluding PCB-126
Rainbow trout	0.19	0.032
Large scale suckers	0.065	0.0095
Mountain whitefish	0.1	0.031

a = Non-detects set at half the detection limit.

In light of the limited samples and concerns discussed above, the PCB-TEQ data was not used to generate cancer risk values. A more sensitive quantitation limit is needed to yield more reliable PCB-TEQs. Although quantitative risk estimates have not been calculated, risks based on dioxin TEQs are potentially significant. It would be highly desirable to have better data on PCB congener levels in Spokane River fish, particularly PCB congener 126.

Appendix D: Evaluating Ingestion Rates for Spokane River Fish Consumers

Estimating ingestion rates is perhaps the most important factor associated with the evaluation of health risk from eating contaminated fish. The differences between fish ingestion rates among the various populations consuming Spokane River fish highlight the need for careful analysis and selection of this important exposure parameter. Recreational anglers were selected as the primary population of concern due to the lack of significant tribal fishing and poor quantification of fish consumption by other populations that fish the river. The available data relevant to consumption of fish from the Spokane River is discussed below.

Lake Roosevelt Recreational/Licensed Anglers

A survey of Lake Roosevelt anglers evaluated the percentage of individuals consuming specific numbers of fish meals per year. The consumption rate per meal in this population was 2.6 fillets and the average trout fillet size was 123 grams for a meal size of 11.3 ounces.[11] This meal size is higher than the usual assumption of eight ounces. EPA recommends a mean and 95th percentile fish meal size of 129 grams (4.6 ounces) and 326 grams (11.5 ounces), respectively.

The number of meals eaten per year was broken down into incremental categories. The lowest two ingestion rate categories ('less than 12 meals/year' and '12-24 meals/year') included 54% of all respondents. It would be plausible then to use 24 meals per year as an approximate average measure. However, since the lowest category, 'less than 12 meals/year', may have included non-fish consumers, the next category ('24-48 meals per year') was used as the basis for a average estimate of 48 meals/year. A high-end estimate of 103.2 meals/year was also selected. Seventy-two percent of all individuals consume 48 or less fish meals per year while ninety-two percent consume less than 103.2 meals per year. Assuming 2.6 fillets per meal and a fillet weight of 123 grams, *average and high-end daily ingestion rates for licensed recreational anglers are 42 and 90 grams per day*, respectively. EPA currently recommends a mean and 95th percentile ingestion rate of 8 and 25 g/day, respectively, for recreational anglers consuming freshwater fish.[41]

Native Americans

Though no studies of Native Americans fishing the Spokane River are available, the Columbia River Intertribal Fish Commission (CRITFC) examined Native American fish consumption rates for tribes fishing the Columbia River Basin.[46] The CRITFC study was selected as the most applicable study for developing a Spokane River fish consumption rate for adults. The median consumption rate, derived by linear interpolation, is 39.2 grams per day. EPA suggests a mean and 95th percentile consumption rate of 70 and 170 grams per day for subsistence Native American consumers.[41] The EPA recommended 95th percentile is in good agreement with the 95th percentile derived from the CRITFC study.

Local Fish Consumption Survey

Information on fish collection and consumption along the Spokane River is available from a 1998 fish consumption survey that was conducted by the SRHD Assessment/Epidemiology Center (SRHD 1998). Populations surveyed in this study included: fishing license holders that rely on the Spokane River for fishing (627 respondents), the Walleye Club (56 respondents), and two ethnic population groups that use the river as a food source (Russian, and Laotian).

To collect information on the Russian and Laotian communities, SRHD hired members of the Russian and Laotian communities to serve as interpreters, translate surveys, and coordinate survey distribution. The response rate for the surveys was minimal and therefore the information obtained from the surveys was inconclusive. Therefore, information was obtained from focus groups. While six people participated in a focus group of the Laotian community, approximately 30 members from the Russian community participated in a similar focus group.

The information obtained from these groups is discussed below. Fish ingestion rates are derived for most of these groups but should be viewed with caution.

- Fishing license holders

Information on *fishing license holders* was collected through a survey that was sent through the mail. Of the respondents, 39.4% indicated that they fish the river. The most common fishing locations were identified as the Spokane Arm of Lake Roosevelt to the Seven Mile Bridge (42.1%), and Long Lake (35.2%). As many respondents did not complete the full survey, information on fish consumption rates for this population is inconclusive. Of the 70 respondents who did complete this portion of the survey, approximately 70% of them reported eating 1-20 fish per year. The most popular types of fish caught and kept by fish license holders include walleye, perch and rainbow trout. None of the fish license holders reported keeping any suckers. The majority of this population (91.1%) eats either skinned fillets or gutted fish. The survey identified a 50th percentile number of fish consumed for licensed anglers. This value is 11.12 fish per year. Assuming that the average fillet size is 123 grams (as used in the cadmium and zinc analysis), the yearly consumption rate is 2,735 grams per year. The daily consumption rate is therefore *7.5 grams per day for the licensed angler.*

- Walleye Club Members

A focus group was held with approximately 20 *Walleye Club members* to collect general information regarding river usage. Surveys were then sent by mail to 180 members of the Walleye Club. Fifty-six completed surveys were received and of the respondents, 40 persons (71.4%) indicated that they fish the river. Like the license holders, the most common fishing locations were identified as the Spokane Arm of Lake Roosevelt to the Seven Mile Bridge (82.5%). Fish consumption rates were not provided for this population. The most popular type of fish caught and kept by the Walleye club members include walleye and rainbow trout. Like the fish license holders, none of the Walleye Club members reported keeping any suckers. Of the Walleye Club members, 80% eat fillets only and 15% eat whole gutted fish. *No ingestion rates were estimated for this group.*

- Russian Community

For the *Russian community*, fishing information was obtained at a focus group. Participants in this group reported fishing at sites within the Spokane city limits, at locations nearest to Greene Street and Plante Ferry Park. The focus group indicated that the Russian community eats fish from the river an average of "one time in two weeks or about four pounds in a month." The "*four pounds in a month*" quote implies that two pounds of fish (900 grams) are consumed per meal, on average, by the population. This value is extremely high compared to other populations studied and *results in an estimated consumption rate of 59.7 grams per day*. The frequency rate of "one time in two weeks" is, however, similar to a value established by ATSDR in 1989 (less than one fish meal per week) (ATSDR 1989).

Many types of fish, as well as crayfish, are caught and consumed by the Russian community. These fish include rainbow trout, crayfish and large-scale suckers. Fish preparation methods in this community include preparing cutlets (ground fish cakes) by grinding fish after removal of the head and spine. These cutlets may therefore include tiny bones. Russian Community members also pickle and dry fish.

- Laotian community

Discussions with the six members of the *Laotian community* revealed that they fished primarily downstream from Seven Mile Bridge. These Laotian community members suggested that *two to three meals of Spokane River fish are consumed per month*, and that with the smaller fish, such as catfish, two fish are consumed per meal. Assuming three meals per month at 2.6 fillets per meal with a fillet weight of 123 grams, *an estimated consumption rate of 31.5 grams per day* is derived.

As trout are difficult to catch, the interviewees indicated that few trout are consumed. Fish consumed by the Laotians include rainbow trout, perch, bass, and walleye. Crayfish are also consumed. Suckers are not consumed by this group and are instead used for bait. Fish preparation methods were not described in the survey.

Summary

Table D1 provides a summary of the estimated fish consumption rates presented above. There is no evidence that subsistence fishing is practiced on the stretch of river between Seven Mile Bridge and the state line. Therefore, the CRITFC data was not considered to be appropriate for derivation of fish consumption rates for Spokane River anglers. The data obtained from the SRHD survey of Spokane River anglers does represent the specific populations of concern but suffered from poor response rates and was not suitable for derivation of a high-end estimate. Further, the rates estimated for the Russian and Laotian communities may not be representative since they were based on relatively small focus groups. The Lake Roosevelt study provides the best data for anglers in the Spokane area. The average and high-end consumption estimates are similar to or higher than estimates presented for other populations except subsistence eaters, which were not identified on the river.

Table D1. Comparison of various fish consumption rates

Population	Fish Consumption (grams per day)		Source
	Average	High-end	
Native Americans (subsistence) [a]	70	170	EPA/CRITFC
Recreational Angler	7.5	NA	SRHD
Recreational Anglers	8	25	EPA
Recreational Anglers	**42**	**90**	**Lake Roosevelt**
Laotian Anglers [b]	31.5	NA	SRHD
Russian Anglers [b]	59.7	NA	SRHD

a = EPA Exposure factors Handbook. These numbers are based in large part on the CRITFC study. However, a better central tendency estimate of the CRTFIC data is the median of 39.2 grams per day
b = The ingestion rates calculated from the local survey conducted by SRHD for these ethnic populations were obtained from very small focus groups.

Appendix E: Background Concentrations of PCBs in Fish

PCBs are ubiquitous environmental contaminants. Environmental processes have resulted in the distribution of PCBs into regions lacking direct PCB inputs. Consequently, it is necessary to discuss "background" concentrations of PCBs in fish tissue.

Factors to Consider in Assessing Background PCB Fish Tissue Concentrations

There are a number of factors to consider in evaluating background PCB concentrations in fish tissue. When characterizing such concentrations in relationship to human health concerns, preparation of samples for PCB analysis should reflect consumption habits of the exposed population. If only fillets are consumed, then PCB concentrations in fillets should be used to characterize background. Conversely, if only whole fish are consumed, then PCB concentrations in whole fish should be used to characterize background. Background PCB levels should be characterized by species because PCBs accumulate to differing degrees among species. Care should also be taken to ensure that sampling locations represent true background and are not impacted by any PCB sources. In addition, use of recent data is desirable because PCBs degrade in fish and other environmental media over time.

Analytical chemistry is also a factor in evaluating PCB background concentrations. Background concentrations should be in units of wet weight, as these are appropriate for assessment of human exposure. The limit of detection for some of the sampling discussed below is 50 ppb. Since background Aroclor concentrations can be less than this value, detections limit should be below 50 ppb.

Ecology's Environmental Assessment Program has obtained Washington State data using more sensitive techniques.[47] The statistic to use in characterizing Aroclor concentrations should be the arithmetic mean, as the mean reflects the exposure experienced by individuals taking fish from the affected resource. However, calculation of the mean is complicated by the use of composite samples and samples with concentrations below the limit of detection. Finally, temporal trends should be considered. It has been observed that Aroclor concentrations in fish tissue may decrease with time.

Data Sources for Background Aroclor Concentrations

Limited data are available to characterize background concentrations of PCBs. Most data are available for Aroclors rather than individual congeners. Congener data are necessary to evaluate dioxin-like PCB toxicity. Possible data sources for evaluating Aroclor tissue background concentrations include: state-wide data from Washington, data from the Northern Rockies Intermontaine Basin (NRIB), data from the Flathead River/Lake region in Montana and data from background sites included in EPA's "National Study of Chemical Residues in Fish".

Ecology's Environmental Assessment Program assembled data on Aroclor concentrations in freshwater fish thought to come from waters without appreciable direct Aroclor sources.[48,49,50] These data are given below in Table E1 and support an Aroclor background level that is less than 50 ppb.

Table E1. Total Aroclor concentrations for background samples in Washington State (ppb, wet weight)

Year	Location	Species	Tissue	n	Total Aroclors	Average by Species	Reference
1999	Ward Lake	Cut throat trout	Fillet	2	13.3	13.3	Serdar, 1999 [a]
1998	Lake Whatcom	Kokanee	Fillet	7-8	9.5	10.5	Serdar et al., 1999 [b]
1998	Lake Whatcom	Kokanee	Fillet	7-8	7.6		Serdar et al., 1999
1999	Ward Lake	Kokanee	Fillet	5	16.4		Serdar, 1999
1999	Ward Lake	Large mouth bass	Fillet	8	19.1	19.1	Serdar, 1999
1998	Lake Whatcom	Long nose suckers	Whole	7	9.5	9.5	Serdar et al., 1999
1997	Douglas Creek	Rainbow trout	Fillet	5	19 [d]	13.3	Johnson, 1998 [c]
1999	Elwha River	Rainbow trout	Fillet	6	17.6		Serdar, 1999
1999	Elwha River	Rainbow trout	Fillet	6	8.8		Serdar, 1999
1999	Elwha River	Rainbow trout	Fillet	6	13.0		Serdar, 1999
1999	Ward Lake	Rainbow trout	Fillet	4	13.6		Serdar, 1999
1998	Lake Whatcom	Sculpin	Whole	7	36	36	Serdar et al., 1999
1998	Lake Whatcom	Small mouth bass	Fillet	8	3.4	6.2	Serdar et al., 1999
1998	Lake Whatcom	Small mouth bass	Fillet	8	9.0		Serdar et al., 1999

a = Reference 54 b = Reference 55 c = Reference 56
d = Some samples were below detection.

Fish tissue Aroclor data from NRIB sampling locations not impacted by direct sources of PCBs were selected on the basis of best professional judgment. [51] These data are listed below in Table E2 and yield an overall average for all fish species of 76 ppb. Computation of these averages is qualitative, as the number of fish in each composite was not known at the time this draft memo was prepared.

Table E2. Northern Rockies Intermontaine Basin (NRIB) background Aroclor fish tissue concentrations (ppb, wet weight) [a]

Species	Date	Concentration	Average by Species
Cutthroat trout	19980707	50	50
	19990901	50	
Large scale suckers	19980708	50	82
	19980812	50	
	19980812	120	
	19980812	50	
	19980818	160	
	19980910	62	
Mountain whitefish	19980616	150	83.3
	19980721	50	
	19980811	50	

a = Reference 49. **NOTE:** Composite samples of 5-10 whole fish.

The United Sates Geological Survey (USGS) examined data from the Flathead River that may also be considered in setting background levels and is given in Table E3. [52,53,54,55] Glacier

National Park is the source for water entering the Flathead Lake/River system. It is thought that such water would be relatively free of contaminants. However, appreciable Aroclor levels were found. USGS suggested that atmospheric deposition might be the source of Aroclor contamination. The total Aroclor values for the Flathead River are higher than those observed elsewhere. The State of Montana collected data for Flathead Lake that is consistent with values seen in the Flathead River. [56] It is interesting to note that whitefish from Flathead Lake had undetectable Aroclor levels whereas lake trout had much higher Aroclor concentrations. These data are given in Table E4.

Table E3. Aroclor concentrations in Flathead River fish (ppb, wet weight) [a]

Year	Species	Total Aroclor	Aroclor-1254	Aroclor-1260	Aroclor-1248
1976	Long nose suckers	200	200		
	Northern pike Minnow	700	500	200	
1978	Long nose suckers	100			100
	Northern pike minnow	640	440	100	100
1980	Large scale suckers	100	100		
	Northern pike minnow	400	300	100	
1984	Large scale suckers	100	100		
	Mountain whitefish	100		100	

a = Reference 50. **NOTE:** All samples were whole body, individual fish)

Table E4. Aroclor levels in Flathead Lake fish (ppb, wet weight) [a]

Species	Size range (in.)	n	Concentration
Lake trout	18-21.6	10	ND
	21.7-26.7	5	80
	27.6-31.1	7	120
	31.4-32.2	6	200
	32.1-34.3	5	220
	34.5-35.2	3	420
	36.5	1	940
	37-38.8	1	41
Lake whitefish	11.4-14.1	9	ND
	15.2-17.7	15	ND
	17.9-18.9	9	ND

a = Reference 54. ND = Not detected.

EPA's "National Study of Chemical Residues in Fish," contains data from fish tissue samples taken in 1987 from twenty "background" sites across the U.S. Sites were selected as minimally impacted by direct sources of contamination based on the best professional judgment of EPA regional staff. The average total Aroclor concentration for samples from background sites was 46.9 ppb with a standard deviation of 108 ppb. [57,58]

Summary

A background range of 13 - 83 ppb PCBs (Aroclor) in Washington State fish can be extracted from the data discussed above. Data collected by Ecology from western Washington water bodies provide a *species-specific background level for rainbow trout fillets of 13 ppb* (see Table E1). These data are considered a good source from which to derive a background level because they were recently collected from a relevant species (i.e., a species consumed by anglers), are derived from fillets, come from true background areas (i.e., no known PCB sources), and are associated with low detection limits. Comparisons made with this background level should be restricted to rainbow trout fillets.

Concentration data from Flathead River and Flathead Lake, MT, seem unusually high relative to other background data. USGS has suggested that atmospheric deposition may be the reason for these high levels. It would be useful to conduct other analyses on “background” water bodies in eastern Washington to determine whether or not the Aroclor concentrations are similar to those found in the Flathead River/Lake system.

References

[1] Hazardous Substances Data Bank. Polychlorinated biphenyls. Toxicology Data Network (TOXNET). http://toxnet.nlm.nih.gov/

[2] Agency for Toxic Substances and Disease Registry. Toxicological Profile for Polychlorinated biphenyls (PCBs). November 2000.

[3] Washington State Department of Ecology. Department of Ecology 1993-94 Investigation of PCBs in the Spokane River. February 1995. Publication No. 95-310.

[4] Washington State Department of Ecology. July 8, 1997. Memo from Art Johnson to Carl Nuechterlein and David T Knight. Subject: 1996 Results on PCBs in Upper Spokane River Fish.

[5] Washington State Department of Ecology. Spokane River PCB Source Monitoring: Follow-up Study, November and December 1995. July 1995. Publication No. 96-331.

[6] Spokane County Health District. Toxic Substances Fact Sheet. Polychlorinated Biphenyls. Revised May 1994.

[7] Spokane Regional Health District. Health Advisory for Spokane River Fish Consumption. August 2000.

[8] Washington State Department of Ecology. September 20, 2000. Memo from Art Johnson to John Roland: Subject: Results from Analyzing PCBS in 1999 Spokane River Fish and Crayfish Samples.

[9] Van den Berg M; Birnbaum L; Bosveld ATC; Brunstrom B; Cook P; Feeley M; Giesy JP; Hanberg A; Hasegawa R; Kennedy SW; Kubiak T; Larsen JC; van Leeuwen FX; Liem AK; Nolt C; Peterson RE; Poellinger L; Safe S; Schrenk D; Tillitt D; Tysklind M; Younes M; Waern F; Zacharewski T. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. *Environ Health Perspect.* 1998;106(12):775-92 .

[10] Calambokidis JC, Jeffries S and Ross P. Temporal trends in contaminants in Puget Sound Harbor Seals. Puget Sound Research 20001: abstracts & biographies. February 12-14, 2001. Bellevue, Washington.

[11] Spokane Regional Health District. 1998 Fish Consumption Survey, Spokane River, Washington: Survey Report. November 1998.

[12] Washington State Department of Health. Consumption Patterson of Anglers who Frequently Fish Lake Roosevelt. September 1997.

[13] Underwood, K. Creel Survey Data Obtained from Lake Roosevelt in 1998, Spokane Tribe, 1998.

[14] U.S. Environmental Protection Agency. Integrated Risk Information System (IRIS2). Internet:

http://www.epa.gov/iris/. February 2001.

[15] Agency for Toxic Substances and Disease Registry and the U.S. Environmental Protection Agency. Public health implications of exposure to polychlorinated biphenyls (PCBs). http://www.atsdr.cdc.gov/DT/pcb007.html.

[16] Cheek A, Kow K, Chen J, Mclachlan JA. Potential mechanisms of thyroid disruption in humans: Interaction of organochlorine compounds with thyroid receptor, transthyretin, and thyroid-binding globulin. *Environ Health Perspect.* 1999;107 (4):273-278.

[17] Gray LEJ, Ostby J, Marshall R, Andrews J. Reproductive and thyroid effects of low-level polychlorinated biphenyl (Aroclor 1254) exposure. *Fundam Appl Toxicol*. 1993;20:288-294.

[18] Byrne JJ, Carbone JP, Hanson EA. Hypothyroidism and abnormalities in the kinetics of thyroid hormone metabolism in rats treated chronically with polychlorinated biphenyl and polybrominated biphenyl. *Endocrinology*. 1987:121:520-527.

[19] Goldey ES, Kehn LS, Lau C, Rehnberg GL and Crofton KM. Developmental exposure to polychlorinated biphenyls (Aroclor 1254) reduces circulating thyroid hormone concentrations and causes hearing deficits in rats. *Toxicol Appl Pharmacol.* 1995;135:77-88.

[20] U.S. Environmental Protection Agency. PCBs: Cancer Dose-Response Assessment and Application to Environmental Mixtures. September 1996. EPA/600/P-96/001F.

[21] Olaya-Contreras P, Rodriguez-Villamil J, Posso-Valencia HJ and Cortez JE. Organochlorine exposure and breast cancer risk in Colombian women. *Cad Saude Publica.* 1998;14(3):125-32.

[22] Adami HO, Lipworth L, Titus-Ernstoff L, Hsieh CC, Hanberg A, Ahlborg U, Baron J and Trichopoulos D. Organochlorine compounds and estrogen-related cancers in women. *Cancer Causes & Control*. 1995;6 (6):551-566.

[23] Hoyer AP, Grandjean P, Jorgensen T, Brock JW and Hartvig HB. Organochlorine exposure and risk of breast cancer. *Lancet*. 1998;352(9143):1816-20.

[24] Moysich KB, Ambrosone CB, Vena JE, Shields PG, Mendola P, Kostyniak P, Greizerstein H, Graham S, Marshall JR, Schisterman EF and Freudenheim JL. Environmental organochlorine exposure and postmenopausal breast cancer risk. *Cancer Epidemiology Biomarkers & Prevention.* 1998;7(3):181-188.

[25] Wolff MS, Toniolo PG, Lee EW, Rivera M and Dubin N. Blood levels of organochlorine residues and risk of breast cancer. *J Natl Cancer Inst (Bethesda)*. 1993;85(8):648-652.

[26] Wolff MS, Zeleniuch-Jacquotte A, Dubin N and Toniolo P. Risk of breast cancer and organochlorine exposure. *Cancer Epidemiol Biomarkers Prev*. 2000;9(3):271-7.

[27] Aronson KJ, Miller AB, Woolcott CG, Sterns EE, Mccready DR, Lickley LQ, Fish EB, Hiraki

GY, Holloway C, Ross T, Hanna WM, Sengupta SK and Weber J-P. Breast adipose tissue concentrations of polychlorinated biphenyls and other organochlorines and breast cancer risk. *Cancer Epidemiology Biomarkers & Prevention.* 2000;9(1):55-63.

[28] Hardell L, Van Bavel B, Lindstrom G, Frederikson M, Hagberg H, Liljegren G, Nordstrom M and Johansson B. Higher concentrations of specific polychlorinated biphenyl congeners in adipose tissue from non-Hodgkin's lymphoma patients compared with controls without a malignant disease. *International Journal Of Oncology*. 1996;9(4):603-608.

[29] Hardell L and Axelson O. Environmental and occupational aspects on the etiology of non-Hodgkin's lymphoma. *Oncology Research*. 1998;10(1):1-5.

[30] Kimbrough RD, Doemland ML and LeVois ME. Mortality in male and female capacitor workers exposed to polychlorinated biphenyls. *J Occup Environ Med*. 1999;41(3):161-71.

[31] Hsieh SF, Yen YY, Lan SJ, Hsieh CC, Lee CH and Ko YC. A cohort study on mortality and exposure to polychlorinated biphenyls. *Arch Environ Health*. 1996;51(6):417-24.

[32] Kuratsune M, Ikeda M, Nakamura Y and Hirohata T. A cohort study on mortality of "yusho" patients: a preliminary report. *Princess Takamatsu Symp.* 1987;18:61-6.

[33] Washington State Department of Fish and Wildlife. May 25, 1994. Memo from John Hisata. to Larry Goldstein. Subject: Spokane River Contamination.

34 U.S. Environmental Protection Agency. Guidance for Assessing Chemical Contamination Data for Use in Fish Advisories. Volume III: Overview Of Risk Management. Office of Science and Technology. Washington DC. August 1996. EPA823B96006.

[35] Roland J. January 26, 2001. Personal Communication, Washington State Department of Ecology, Eastern Regional Office, Spokane, WA.

[36] Washington State Department of Health. Eating Fish from Lake Roosevelt. Office of Environmental Health Assessments. http://www.doh.wa.gov/ehp/oehas/FS_dioxitab.pdf

[37] United States Geological Survey. Are walleye from Lake Roosevelt contaminated with mercury? USGS Fact Sheet FS-102-97 by Martha L. Erwin and Mark D. Munn. August 1997. http://wa.water.usgs.gov/reports/fs.102-97/.

[38] Alaska Division of Public Health. The Use of Traditional Foods in a Healthy Diet in Alaska: Risks in Perspective. January 15, 1998.

[39] U.S. Environmental Protection Agency and Toxicology Excellence for Risk Assessment. August Comparative Dietary Risks: Balancing the Risks and Benefits of Fish Consumption. August 1999.

[40] American Heart Association. An Eating Plan for Healthy Americans.

http://www.americanheart.org/dietaryguidelines/images/EatPlan2000.pdf

[41] Ponce RA, Bartell SM, Wong EY, LaFlamme D, Carrington C, Lee RC, Patrick DL, Faustmann EM and Bolger M. Use of quality-adjusted life year weights with dose-response models for public health decisions: A case study of the risks and benefits fish contaminants. *Risk Anal.* 2000;20(4):529-42.

[42] U.S. Environmental Protection Agency. Exposure Factors Handbook: Volume II - Food Ingestion Factors. Office of Research and Development. Washington DC. August 1997. EPA/600/P-95/002Fb.

[43] U.S. Environmental Protection Agency. Guidance for Assessing Chemical Contamination Data for Use in Fish Advisories. Volume II: Risk Assessment and Fish Consumption Limits. Third Edition. Office of Science and Technology. Washington DC. November 2000. EPA 823-B-00-008.

[44] Great Lakes Sport Fish Advisory Task Force. Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory. September 1993.

[45] Vielmetti, AF. A Retrospective Interpretation of PCB Concentrations in Fish Tissue. M.S. Thesis. University of Washington, Department of Environmental Health. 1996.

[46] Columbia River Inter-Tribal Fish Commission. A Fish Consumption Survey of the Umatilla, Nez Perce, Yakima, and Warm Springs Tribes of the Columbia River. October 1994. Technical Report 94-3.

[47] Johhnson A. November 16, 2000. Personal Communication with Lon Kissinger. Washington State Department of Ecology, Environmental Assessment Program, Olympia, WA.

[48] Serdar D. PCB Concentrations in Fish from Ward Lake (Thurston County) and the Lower Elwha River. Washington State Department of Ecology, Environmental Assessment Program, Olympia, WA. September 1999. Pub. No. 99-338.

[49] Serdar D, Davis D, and Hirsch J. Lake Whatcom Cooperative Drinking Water Protection Project: Results of 1998 Water, Sediment and Fish Tissue Sampling. Washington State Department of Ecology, Environmental Assessment Program and Hirsch Consulting Services, Olympia and Bellingham, WA. September 1999. Pub. No. 99-337.

[50] Johnson A. 1998. Rainbow trout Abnormalities in Douglas Creek: Results from Chemical Analyses. Memorandum to T. Jackson. Washington State Department of Ecology, Environmental Assessment Program, Olympia, WA.

[51] Maret TR. November 2, 2000. Personal Communication with Lon Kissinger. U.S. Department of the Interior, U.S. Geological Survey, National Water-Quality Assessment Program.

[52] Maret TR and Dutton DM. Summary of Information on Synthetic Organic Compounds and

Trace Elements in Tissue of Aquatic Biota, Clark Fork-Pend Oreille and Spokane River Basins, Montana, Idaho and Washington, 1974-96. U.S. Department of the Interior, U.S. Geological Survey, National Water-Quality Assessment Program. 1999. Water-Resources Investigations Report 98-4254.

[53] Schmitt CJ, Zajicek JL and Ribick MA. National Pesticide Monitoring Program: residues of organochlorine chemicals in freshwater fish, 1980-81. *Arch Environ Contam Toxicol.* 1985;14(2):225-60.

[54] Schmitt CJ, Ribick MA, Ludke JL and May TW. 1983. National Pesticide Monitoring Program - Organochlorine Residues in Freshwater Fish, 1976-79: Washington D.C. Fish and Wildlife Service, Resource Publication 152, 62 p.

[55] Schmitt CJ, Ludke JL and Walsh DF. Organochlorine Residues in Fish – National Pesticide Monitoring Program, 1970-74. *Pestic Monit J*. 1981;14(4):136-206.

[56] Phillips G and Bahls L. Lake Water Quality Assessment and Contaminant Monitoring of Fishes and Sediments from Montana Waters. Final Report to U.S. Environmental Protection Agency prepared by Montana Department Fish, Wildlife and Parks and the Montana Department Health and Environmental Sciences. 1994.

[57] U.S. Environmental Protection Agency. National Study of Chemical Residues in Fish, Volume I. Office of Science and Technology, Washington DC. September 1992. EPA 823-R-92-008a.

[58] U.S. Environmental Protection Agency. National Study of Chemical Residues in Fish, Volume II. U.S. Office of Science and Technology, Washington DC. September 1992. EPA 823-R-92-008b.